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ABSTRACT

Information that school facility personnel can use concerning the potential impacts of renovation projects on indoor air quality (IAQ), along with details of some effective control strategies, are presented. Various kinds of contaminants may be generated by renovations, including volatile and semivolatile organic compounds, dusts and fibers (e.g., asbestos), gases (e.g., sulfur dioxide), bioaerosols (e.g., mold and fungus spores), and physical agents (e.g., noise and uncomfortable temperatures). Some IAQ control strategies include the inspection of all building materials; overseeing heating, ventilating, and air-conditioning considerations; scheduling classes around construction; relocating persons who may be particularly susceptible to airborne agents; and notification/communication, which includes early involvement of the school principal, responding to problems and emergencies, and informing all affected parties. It is recommended that careful work site preparation be made to minimize the release of airborne agents. Construction administration, therefore, is an important component of maintaining good IAQ, as is the need to establish uniform acceptance criteria for all renovation projects. (Contains 10 references, 1 table, and 2 figures.) (RJM)

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MAINTAINING ACCEPTABLE INDOOR AIR QUALITY DURING THE RENOVATION OF A SCHOOL

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Introduction

The goal of this bulletin is to provide school facility personnel with information concerning the potential impacts of renovation projects on indoor air quality (IAQ) and effective control strategies. The bulletin discusses techniques to maintain comfort and low pollutant levels for the protection of occupants; heating, ventilating, and air conditioning (HVAC) systems, and other equipment.

School facilities are occupied by an increasingly diverse population who, because of their age, pre-existing medically diagnosed illnesses, or, in the case of the young and special education students, inability to communicate, may be at increased risk to IAQ-induced health effects.

Renovation activities can create IAQ problems owing to construction processes and the large quantities of particulates, gases, and vapors that may be generated by disturbing existing materials or by introducing new materials.

Furnishings (especially those with fabrics) and mechanical systems may become contaminated by these pollutants. In turn, they may spread contamination, (via the HVAC system), or act as pollutant "sinks" by adsorbing volatile contaminants and then serving as long-term emission sources.

It should be noted that the recommendations, techniques, and procedures presented in this bulletin are not applicable to all types of renovations or maintenance activities. For example, "touch up" painting, and renovations of areas not occupied by students or facility personnel, such as some mechanical rooms and storage areas, often do not require extensive control strategies. Also, this document is not intended to address all of the regulatory requirements that will apply to renovations that require disturbing certain highly regulated substances, such as asbestos-containing materials, and, in some jurisdictions, lead-based paint.

Contaminants, Sources, and Hazards

This section is organized by type or class of contaminants that may be generated by renovation-related activities. This presentation is not all-inclusive, but is intended to present and discuss some of the more common or problematic contaminants within the class, known sources of the contaminants, and an overview of potential health effects associated with the contaminants. The potential hazards presented by these contaminants should not present a problem if proper control techniques, presented later in this bulletin, are applied.

A. Volatile and Semi-Volatile Organic Compounds

For the purposes of this bulletin, volatile organic compounds (VOCs) are defined as those compounds that are readily volatilized (given off as a gas) from building materials. Semi-volatile organic compounds (SVOCs) are defined as those that will be volatilized, but at a much slower rate.

Hundreds of VOCs have been identified by indoor air quality studies. Renovation projects typically involve introducing numerous sources that are known to be emitters of VOCs. These sources include protective coatings, sealants, paints, stains, varnishes, adhesives, caulking compounds, carpeting, resilient floor coverings, and wall coverings. Paints, stains, and varnishes may emit a wide variety of VOCs including aliphatic (hexane and octane), aromatic (toluene and xylenes) and oxygenated hydrocarbons such as alcohols (butyl, isopropyl), ketones (methyl ethyl and methyl isobutyl), and glycol ethers (2-ethoxyethanol and 2-ethoxyethanol acetate). Sealants and caulking materials emit xylenes and aliphatic hydrocarbons. Carpeting can emit a number of VOCs including styrene, formaldehyde, and 4-phenylcyclohexene. Wall coverings have been found to emit methyl ethyl ketone, tetrahydrofuran, toluene, xylenes, and formaldehyde. Resilient flooring emissions include various aliphatic hydrocarbons, trimethylbenzene, benzyl chloride, and formaldehyde.

There is a wide range of potential health effects associated with human exposure to these compounds. Many VOCs, in concentrations sometimes found during industrial operations, can affect the central nervous system, acting as depressants and anesthetics. Others have "target organs," such as the liver, kidneys, brain, and blood, as well as the reproductive organs. Many also act as irritants to the eyes, nose, and throat.

A common source of SVOCs is coal tar pitch used in some roofing applications. Coal tar pitch is the product of the destructive distillation of bituminous coal and contains many polycyclic aromatic hydrocarbons (PAH's), a number of which are recognized carcinogens. In addition to containing carcinogenic PAH's, the emissions from heated coal tar pitch are also irritating. It is quite common for the emissions from heated holding kettles to be drawn inside the building being renovated and cause widespread complaints. Some specific PAH's found in "coal tar pitch volatiles" are naphthalene, benzo(a)-pyrene, phenanthrene, acridine, chrysene, anthracene and pyrene. Hot asphalt emissions contain some of the same PAH's and can create similar indoor air complaints, although usually not as intense.

Very limited research has been conducted linking specific VOCs at known common (non-industrial) indoor air concentrations to effects on human comfort and health. Concentrations are ordinarily 100 to 1,000 times lower than occupational exposure limits. Studies have shown that the most frequent effects of low level VOC exposures are stimulation of the senses, inflammation of exposed tissues, and stress-like reactions such as headache or fatigue.

Minimizing building occupant exposure to VOCs is a responsible and reasonable policy for building managers.

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B. Dusts and Fibers

Another major class of indoor pollutants is particulate matter. Dusts and fibers are the specific types of particulates discussed in this subsection. Dusts and fibers may be released during renovation activities such as cutting and sanding, as well as by simply disturbing areas where dusts and fibers have accumulated over time. Many of the dusts generated by renovation activities are termed "nuisance dusts." These are materials that do not cause lung fibrosis or systemic health effects, and are generally thought to be "nontoxic" unless present at high concentrations. Examples of nuisance dusts are: Portland cement, gypsum, limestone, and Plaster of Paris. Other dusts may be associated with systemic health effects. A common toxic particulate that may be encountered during renovation activities is dust generated by disturbing lead-based paint. In addition to the dust presenting an inhalation hazard, the dust may be ingested; especially by younger children, when contaminated fingers and hands are placed in the mouth. Even relatively low levels of lead exposure can lead to cognitive and developmental deficits in children that can persist into adulthood. Other symptoms of lead poisoning

include gastrointestinal disturbances, fatigue, weakness, headache, and personality changes.

Fibers that are commonly encountered in the indoor environment include fiberglass and asbestos. Fiberglass fibers can be readily released when fiberglass thermal insulation and duct lining are disturbed. Fiberglass is very irritating and has been identified as the cause of skin irritation in some "sick building syndrome" investigations. In addition, the potential carcinogenicity of fiberglass has been the subject of much research, and the National Toxicology Program has recently stated that sufficient evidence exists for the carcinogenicity of glasswool (fiberglass) in experimental animals.

Asbestos was once widely used in structural fireproofing and thermal insulation. Other asbestos-containing materials that may be encountered during renovations are floor and ceiling tiles, mastic, plaster, drywall, and roofing materials. Inhalation of asbestos fibers has been shown to cause three diseases: fibrosis of the lung (asbestosis), lung cancer, and cancer of the lining of the chest or abdominal cavity (mesothelioma). All schools are required by the Asbestos Hazard Emergency Response Act (AHERA) to have asbestos management plans in place that identify all of the asbestos-containing materials present in the building(s).

C. Gases

Combustion sources that may be used at renovation sites emit various gases. Internal combustion engines (motor vehicles, generators) and space heaters produce carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO, NO_2), and sulfur dioxide (SO_2). Welding processes can produce ozone (O_3), as well as CO, NO, and NO_2. Carbon monoxide is an asphyxiant, exerting its action through disrupting oxygen transport in the blood. The elderly, fetuses, and persons with cardiovascular and pulmonary diseases are particularly sensitive. Symptoms of exposure to CO may mimic influenza and include fatigue, headache, dizziness, nausea, inability to concentrate, and rapid heartbeat.

Nitrogen dioxide and sulfur dioxide act mainly as eye, nose, throat, and respiratory tract irritants. Sulfur dioxide may also cause bronchial constriction in people with asthma. Nitrogen dioxide can reach the lower airways causing sensitive reactions in some asthmatics, decreased lung function in patients with pulmonary disease, and increased risk of respiratory infections.

Ozone is produced during arc welding. The ultraviolet radiation produced by the arc causes a photochemical reaction whereby atmospheric oxygen is converted to ozone. Ozone is very irritating to the upper and lower respiratory tract, and causes local irritation to the eyes and mucous membranes.

D. Bioaerosols

Biological pollutant sources include outdoor air, people carrying viruses and bacteria, and various animals that shed allergens (substances that cause allergic reactions; symptoms include conjunctivitis, rhinitis and bronchitis). Indoor surfaces and water reservoirs where fungi and bacteria can grow are also potential sources of biological pollutants. Airborne biological materials (bioaerosols) have been shown to produce three types of human disease. These are infections, hypersensitivity diseases involving immune system activation, and toxicoses whereby chemical toxins are released and cause toxic effects.

Large quantities of spores and other biological material can be aerosolized if contaminated building materials, furnishings, and equipment are disturbed during renovations. These large releases of biological materials present a risk to all building occupants especially those predisposed to or already suffering from allergic rhinitis (approximately 20% of the population) and asthma (8-12%).

Fungus (or mold) spore allergens are known to cause hay fever (allergic rhinitis), asthma, and hypersensitivity pneumonitis. A number of common indoor fungi have been associated with allergic rhinitis and asthma.

The major sources of indoor allergens are dust mites, domestic pets, and cockroaches, as well as fungi and other microorganisms. The allergens produced by these organisms become airborne and can cause various allergic diseases such as hay fever, asthma, and hypersensitivity pneumonitis. Dust mites are thought to be a major cause of childhood asthma. Allergens released by house pets are an important cause of allergic rhinitis and asthma. Cockroach allergens can also play a significant role in the development of allergic rhinitis and asthma.

Bacterial infections have been documented for indoor air exposures to certain bacteria, including Legionella pneumophila (Legionnaire's disease). Common sources of these bacteria are cooling tower water (Legionella), and cool-mist vaporizers and nebulizers. Several pathogenic fungi have also been identified in bird and animal droppings.

E. Physical Agents

In addition to the pollutants discussed above, renovation activities can introduce physical stressors to the school building (noise, vibration) and create uncomfortable temperature or humidity.

The addition of demolition/construction-related noise and vibration can adversely impact the ability to concentrate and communicate in the office and learning environment. Sources of noise include the various mechanical methods used to demolish existing components and construct new ones, as well as generators and vehicles. Jackhammers used to break concrete and paving are a common source of distracting vibration.

Without control strategies, it is likely that renovation activities will adversely impact the ability to control temperature and humidity within the school, especially those areas adjoining the space undergoing renovation. Student, teacher, and administrative staff performance will be diminished if comfort levels are not maintained within the range recommended by the American Society of Heating, Refrigerating and Air Conditioning Engineers' Standard 55—Thermal Environmental Conditions for Human Occupancy. Spaces below 68°F and 30% relative humidity in the winter, and above 78°F and approximately 60% relative humidity in the summer may be expected to produce an increase in discomfort complaints.

IAQ Control Strategies

A number of control methods are available to reduce the likelihood that renovation projects will create IAQ problems. These include: early identification of hazards presented by the existing building materials, furnishings, and equipment; selecting appropriate new building materials, and storing and installing them properly; selecting and applying ventilation controls, and utilizing temporary barriers; minimizing exposure through appropriate scheduling; relocating susceptible individuals; communicating with all impacted personnel; minimizing release of pollutants through applying good housekeeping and work practices; utilizing a management control system during the project; and incorporating these practices into the bid specifications. Each of these controls are described in more detail below.

A. Existing Building Materials

It is important to inspect the area to be renovated well in advance. This will allow time to identify potential hazards and to assess them. Laboratory analyses may be necessary to ensure the building, occupants, and personnel performing the remediation are properly protected. Significant lead time may be required if contract specifications, specific to the hazards involved, are to be utilized.

Inspection Should Evaluate:

- Microbial growth on water damaged materials or in standing water (carpets, ceiling tile, roof decks)
- Contamination by bird/animal droppings
- Presence of lead-based paint
- Presence of polychlorinated biphenyls (PCBs) in light ballasts
- Presence of asbestos-containing materials (reference required AHERA reports)

If the building was constructed prior to 1980, it is advisable to utilize the services of an appropriately trained professional to perform a lead paint inspection unless such studies have been completed, documented, and provide the required information. The previously conducted inspections required by AHERA regulations will provide sufficient information on asbestos-containing materials.

B. New Building Materials

Many new building products are recognized as sources of indoor pollutants. General precautions to take when procuring new materials include specifying low VOC emitting paints, adhesives and composite materials. Examples would include using latex instead of oil-based paints, hardwood instead of chipped/pressed plywoods, and water-based instead of solvent-based glues and adhesives. For furnishings, specify low formaldehyde-emitting fabrics and continuous filament carpeting to reduce shedding.

A Material Safety Data Sheet (MSDS) should always be obtained for each product considered for use in the renovation project. In addition, school systems should require manufacturers to include the following information:

- The material contents of the product
- Identification and quantified amounts of substances that are listed on: (a) the International Agency for Research on Cancer List of Chemical Carcinogens; (b) the Carcinogen List of the National Toxicology Program; or (c) the Reproductive Toxin List of the Catalog of Teratogenic Agents

Table 1. Comparison of Dilution and Local Exhaust Ventilation

Dilution	Local Exhaust
• Lowers concentration of pollutants by introducing supply air to the space that includes filtered, recirculated air and outside air.	• Captures pollutants near their source and exhausts outdoors

• Used only for low hazard situations (Small quantities of low VOC-emitting materials used and/or small amounts of "nuisance" dust produced)	• Incorporates barriers and negative pressure
	  ◦ ventilation unit(s) ducted to outside
	  ◦ area sealed off to create negative pressure
	  ◦ make-up air provided from another location
	  ◦ HVAC system isolated (registers/grilles sealed off)

• Assumes outdoor air is of good quality	

General precautions to take when procuring new materials include specifying low VOC emitting paints, adhesives and composite materials.

Larger school systems, or a consortium of school systems, may wish to consider asking manufacturers to supply additional data on their products when their product will be used in significant quantities and/or to qualify for projects during a specific time period (e.g., one year). For example, a school system may identify a limited number of high usage products and require manufacturers to submit data on:

- Product TVOC emission factor (e.g., 1, 7, 30 days after manufacture for solid products such as carpet and 1, 4, 24, 48 hours for wet products such as adhesives) (mg/m^2•hr)
- The emissions test protocol used
- The laboratory evaluating the product

While emission data can be used to evaluate products, a small difference between products may not be meaningful or provide a basis for selection. Other factors to be considered include initial cost, expected life of the product, maintainability, and aesthetics.

The following are additional approaches that can be implemented to reduce the IAQ impacts of new building materials.

- Air out carpeting, vinyl flooring, work station panels, and other fabrics to reduce residual VOC levels. This can be accomplished prior to packaging at the factory, after receipt in a warehouse, or at the construction site.
- For "wet" products (e.g., adhesives, sealants, paints), require the manufacturers to specify (and the installers to follow) procedures that allow for the smallest quantities of the products to be utilized, consistent with performance requirements.

Note that when new materials are stored, they should be protected against water damage and high humidity to guard against mold growth. "Fleecy" furnishings should be stored away from strong sources of pollutants since these items may adsorb VOCs (act as "sinks") and then emit them over an extended period of time.

It may also be necessary to control humidity in the renovation area to inhibit mold growth. Likewise, the renovation area should be provided with outdoor air ventilation and maintained at a temperature of at least 60°F after new materials are introduced to promote chemical off-gassing before reoccupancy.

C. HVAC Considerations

There are two general types of ventilation that are utilized to control indoor pollutants; dilution, and local exhaust combined with isolation techniques. Table 1 compares the two types.

A local exhaust system may be as simple as setting up floor fans and/or window fans to ventilate directly outside if the room has operable windows or doors to the outside. In the absence of direct access to the outside, portable ventilation units can be used that have flexible ducting so the exhaust air can be ducted to the nearest available window or door. If this method is used, the door through which the exhaust air is exiting the room must be sealed so a negative pressure is

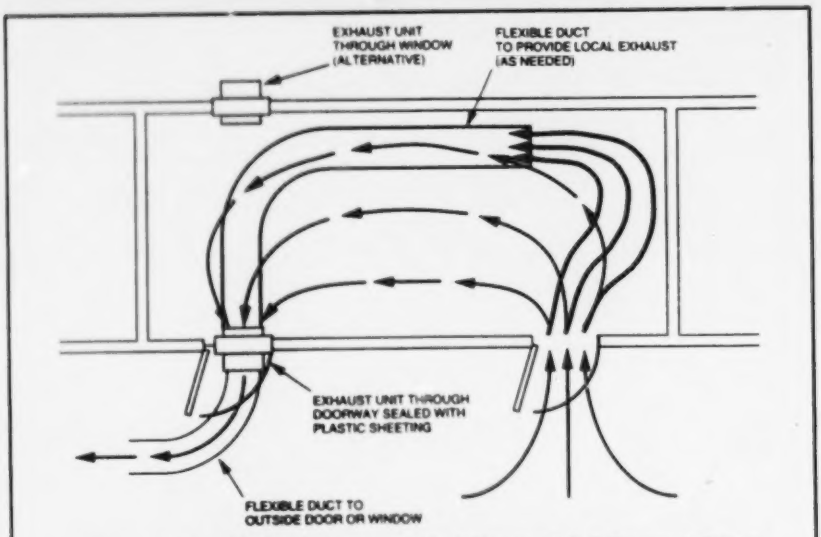
EXHAUST UNIT THROUGH WINDOW (ALTERNATIVE)
FLEXIBLE DUCT TO PROVIDE LOCAL EXHAUST (AS NEEDED)
EXHAUST UNIT THROUGH DOORWAY SEALED WITH PLASTIC SHEETING
FLEXIBLE DUCT TO OUTSIDE DOOR OR WINDOW

Figure 1. Ventilation of a Renovated Room with 2 Doors (plan)

set up within the room and make-up (dilution) air is provided from another location, preferably at a point where the dilution air sweeps across as much of the renovation area as possible (see Figure 1).

If the use of the school's HVAC system is being considered for exhausting air from the space, it is imporant to avoid contamination of the system. Toxic dusts may be generated from demolition and surface preparation (scraping and sanding). These dusts may then accumulate within the system and become dislodged and entrained in the air being handled by the system at a later date. Likewise, vapors may be adsorbed on HVAC system components and later released. This is of special concern for the renovation of buildings where the ductwork may have interior soundproofing material. Temporary filters can be installed at the face of each return grille to reduce the potential for system contamination. However, it is always preferable to use other exhaust techniques which are independent of the building's HVAC system.

When devising a ventilation control strategy, it is important to eliminate the potential pathways that will allow contaminants to migrate into occupied areas. First, the contaminants may enter the HVAC system and be dispersed throughout the school building. This may occur by entering return grilles that may not be entirely sealed off, or by being drawn back into the building because pollutants are exhausted too closely to the outdoor air intake. Unless the renovation space is under negative pressure (in comparison to adjoining spaces), pollutants will migrate through existing holes and cracks in walls, etc., or hidden pathways such as above drop ceilings or under raised flooring. Once identified, it is usually easy to devise techniques to eliminate these pathways.

D. Scheduling

It is important that scheduling information be disseminated to all affected parties, including school administrators, teachers, maintenance and operations staff, contractors, parents, and students as appropriate. Whenever possible, major work should be scheduled during unoccupied periods, or periods of least occupancy. This is especially important for those tasks that will produce the most dust, odor, VOC emissions, and/or emissions of more potentially toxic components. Consideration should also be given to minimizing occupancy for a period of time after the renovation (at least 1-2 weeks whenever possible) to minimize exposures to pollutants being emitted during the "curing" or off-gassing period. Large projects should be scheduled during the summer "vacation" months. It is unrealistic, however, to expect all renovations to occur only when a building is unoccupied. Incorporation of the various control methods presented in this bulletin will allow many renovations to be conducted while the building is occupied. Even if unoccupied, the project areas should be ventilated as discussed above.

E. Relocation of Susceptible Persons

It is always prudent to move as many people as possible away from a potential pathway for migration of pollutants from the renovation area. Strategies that can be employed include moving classrooms and offices to another area of the building, or to move to another building entirely. To make room within the building, it may be necessary to schedule two "shifts" if the renovation must be conducted during the session. If another building is not available, it may be appropriate to provide temporary classrooms to accommodate affected students and teachers. Relocation may be required for individuals with medically documented hypersensitivities to pollutants (including asthma). Another option for hypersensitive students would be home instruction for an appropriate period of time.

F. Notification/Communication

A strong, proactive communication and notification program should be established. Such a program can help prevent IAQ problems and establish mechanisms for all parties to cooperatively resolve IAQ issues if they do arise. Elements of a recommended program are presented below.

1. Early Involvement of School Principal
   - Briefed on planned work
   - Provides scheduling assistance
   - Communicates special concerns (sensitive individuals, problem areas)
   - Provided with MSDSs and information as to how materials were selected
   - Participates in disseminating information to all affected parties
2. Response to Problems and Emergencies
   - Identify individual responsible for providing timely response to IAQ problems during the renovation
   - Individual should be available and familiar with building systems, occupants, and renovation activities
   - Ensure emergency response plans are appropriate for renovation activities
   - Consult with Fire Marshal to ensure escape routes/exits are not impacted
   - Post appropriate signage (projects involving asbestos and, in some states, lead have specific regulatory requirements)
3. Communication With Affected Parties
   - Provide overview of how groups

(staff, teachers, students) will be affected (disruption of normal routines)

- Provide summary of steps taken to minimize potential problems
- Encourage input and allow for expression of concerns
- Make MSDSs available to anyone at a convenient location
- Include parents in process by sending memorandum or flyer that provides the same information noted above and identifies a point-of-contact for parents' questions and concerns
- Provide periodic updates as the renovation progresses
- Provide information on low-level residual offgassing that may still be occurring (and continually declining) when the space is reoccupied, and on the dilution provided by the HVAC system

In all communication matters it is important to provide **advance** notice and information. This helps build trust and allows the occupants to feel they are part of the process. It also provides time for questions to be answered. At no time should the appearance be given that information is being withheld. The person communicating information to the occupants should be someone who has, or can readily gain, everyone's trust.

G. Job Site Housekeeping/ Work Practices

Various techniques and good practices can be applied to renovation projects to minimize the release of pollutants. Initially, workplace preparation should include removing, or otherwise protecting as many items of furniture, supplies, and other articles, as possible from the work area. Many of these items, especially fabrics, may adsorb vapors and then slowly release them back to the room air after reoccupancy of the space.

Consideration should be given to the construction of barriers (e.g., walls or curtains of plastic sheeting) to minimize the distribution of dust and other pollutants.

Careful attention must be given to workers and equipment leaving the renovation area to avoid carrying dusts and fibers outside of the work area. Adherence to simple good housekeeping practices eliminates this pathway for contaminants. Provision of walk-off mats at exits, and removal of coveralls and wiping down equipment before exiting work area are effective practices.

Figure 2. Potential Contract Specification Topics

- Notification/Communication
- Schedule (minimizing exposure)
- Selection of Building Materials
- Protection of HVAC System, Other Critical Systems, and Furnishings
- Isolation Techniques, Use of Negative Pressure
- Ventilation/Filtration Requirements
- Work Practices/Procedures
- Housekeeping
- Material Storage
- Project Inspection/Monitoring
- IAQ Standards and Guidelines to be Applied
- Close-out Criteria

The spread of dusts may also be controlled by:

- Incorporating "wet techniques" when cutting into or tearing out dust-producing materials such as concrete
- Wiping down all surfaces with a wet cloth after completing dust-generating activities in an area
- Using only high efficiency particulate air (HEPA) filter-equipped vacuums to vacuum up fine or potentially toxic dusts

To control the emissions of VOCs and SVOCs:

- Place lids back on containers each time they are used
- Pour out only the amount that will be used up before the next break in work activities
- Pour materials back into containers and seal before taking lunch or other lengthy break, and at the end of the day
- Store paint thinner and rags used with thinner in sealed containers
- Clean up spills as soon as possible
- Adhere to manufacturers' recommended product installation/application procedures to avoid using too much material leading to increased emissions

Incorporation of good pest management practices is also important during renovation projects. Some pests are mainly nuisances (flies, other insects), while others (mice, birds) can create significant IAQ problems (biological hazards from droppings, odors from decaying animals in hidden/inaccessible areas). Integrated pest management (IPM) is the approach of choice. IPM emphasizes the use of non-chemical techniques for the management of pests, relying on the use of pesticides only when non-chemical strategies are not effective.

Finally, it is critical that, upon completion of the job, wastes and leftover materials are properly managed. It may be appropriate to retain some or all of the left-over material for some period of time. If so, ensure all containers are tightly sealed and stored properly. Materials should never be stored in HVAC mechanical rooms. Inevitably, there will be some leakage of VOCs from containers; therefore, it is important that the storage area be located such that the air is not drawn into occupied areas. Migration of VOCs may occur if the storage area is not vented to the outside, if the storage area is located within the school and is under "positive pressure" with respect to the adjoining area, or if the vapors are exhausted/vented close to an outdoor air intake. Therefore, it is not recommended that wet products be stored within the school in quantities greater than deemed necessary for efficient functioning. Since most VOCs are flammable, fire codes may provide additional guidance on storage requirements.

H. Construction Administration

All renovation projects should be performed under a management control system to ensure correct work practices are being utilized, and specifications are being adhered to. Small projects may be administered, on a collateral duty basis, by an appropriate staff person. Larger projects will warrant regular oversight and monitoring, and for managing a permit system that requires sign-off before each major phase may proceed. The person providing oversight should have well defined authority, duties/responsibilities, and possess the necessary skills and knowledge. This person will also perform routine monitoring to ensure any pre-established IAQ standards/guidelines are not exceeded during the renovation and that "decontamination" criteria are met upon completion. To verify adherence to contract specifications, day-to-day oversight should include inspections. While model IAQ-related contract specifications are not available, school systems may develop specifications that address any or all of the topics discussed in this bulletin (see Figure 2).

Qualitative and quantitative air quality criteria can be established for renovation

projects. Qualitative air quality criteria include gross indicators of contamination. For example, it may be specified that renovation work shall not allow visible haze, settled dust, or detectable odors to migrate to occupied areas. These qualitative criteria are inexpensive to administer since they require no instrumentation or significant investments of time. However, since they are subjective, this application can be a source of disagreement between the project monitor and the contractor. Also, it can be argued that in some cases they are not sensitive enough indicators to protect building occupants, especially sensitive individuals.

Quantitative criteria can include regular measurements of pressure differentials, and use of direct-reading instruments for classes of pollutants. For example, direct-reading particulate monitors are now readily available; and portable, direct-reading instruments utilizing photoionization detectors are routinely used to screen for a wide range of VOCs. In addition, a wide array of instrumentation and sampling methods may be specified for individual pollutants of concern.

Drawbacks to the quantitative approach are that measuring for pollutants is generally expensive and time consuming, and that appropriate IAQ exposure limits for non-occupational settings have not been agreed upon by the scientific and regulatory communities. Also, the direct-reading dust and VOC instruments will not identify the specific pollutants that make up "dust" or "total VOCs." Therefore, if the potential emissions are not fully characterized, there is a risk that unanticipated toxic compounds may be generated and monitored generically as a "nuisance" dust or a common VOC. Note also that regulatory requirements exist that specify the monitoring to be performed when asbestos (and lead in some jurisdictions) are encountered.

Drawbacks to the quantitative approach are that measuring for pollutants is generally expensive and time consuming, and that appropriate IAQ exposure limits for non-occupational settings have not been agreed upon by the scientific and regulatory communities.

Qualitative indoor air quality criteria are recommended. Quantitative criteria generally should be limited to temperature, relative humidity and pressure differentials as required. Monitoring for specific pollutants is generally not recommended unless circumstances clearly indicate its usefulness.

Project Close-Out

It is important that IAQ-related close-out, or acceptance criteria be established for all renovation projects. Close-out criteria can be specified, as necessary, in the following areas.

- General cleaning—all surfaces should be wet-wiped and all areas vacuumed (HEPA-equipped for fine and/or potentially toxic dusts).
- Specify portions/components of HVAC system to be cleaned and inspection criteria to be utilized (e.g., visually clean or quantitative test). Borescopes or remote video camera systems may be used for inspection of inaccessible areas.
- Balance and test HVAC system if any system modifications (e.g., relocation of ducts, grilles) have been performed, or if areas served by the system have been altered (e.g., addition or deletion of walls, doors, openings). Specify balancing report requirements, ensure adequate outdoor air is provided under all cooling and heating load conditions.
- Dispose of filters that may have been contaminated during the renovation, and ensure appropriate replacement filters are installed.

When required, the HVAC system should be tested and balanced in accordance with applicable "test and balance" (TAB) industry practices. The TAB contractor should be a certified member of a recognized professional association such as the Associated Air Balance Council, or the National Environmental Balancing Bureau.

Each HVAC system should be tested and verified for each mode of operation, including:

- Occupied/unoccupied
- Warm up/cool down
- Ventilation cycle
- Emergency power supply

Typical components and system parameters to be tested include:

- All supply, return, exhaust, and outdoor airflow rates
- Control settings and operation
- Air temperatures
- Fan speeds and power consumption
- Filter resistance

Properly performed testing and balancing will verify system operation within design specifications, identify and correct any problems, and ensure system safety.

Note that if the HVAC system is renovated (vs. minor modifications), then a commissioning process such as that described in ASHRAE Guideline 1-1989 should be undertaken. HVAC commissioning:

- verifies that performance meets design intent,
- generates appropriate system documentation, and
- trains operation and maintenance personnel.

Pre-Occupancy and Occupancy

Ideally, a 1-2 week pre-occupancy period should be scheduled to allow for curing of finishes and off-gassing of pollutants. During this period the space should be continuously ventilated with maximum outdoor air. The space should also be maintained above 60°F to maintain acceptable curing temperature, and the air dehumidified, if necessary, to prevent microbial growth. For projects involving extensive quantities of "wet" products, it may be necessary to provide local exhaust ventilation for a period of time before using the building HVAC systems in order to minimize VOC contamination.

The outdoor air supply to newly occupied space can also be increased for an initial 30-60 day period to help control the residual off-gassing that will continue, albeit at low levels. This can be accomplished by operating the HVAC system at maximum outdoor air and/or extending the hours of system operation. The need for this measure should be evaluated based on the nature and quantity of existing and new materials in the project.

Management and health and safety personnel should be alert to problems that may occur in the first several months of the occupancy period. Personnel should respond quickly to complaints and be prepared to provide a credible response. As during the renovation, communication is critical, and occupants should be provided information and communication opportunities.

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